Analytical methods and new tecnologies for geometrical analysis and geo-referenced visualisation of Historical Maps

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ABSTRACT

The need and desire to produce instruments for the understanding and fruition of the historic cartography are born from these considerations: the understanding of the contents of the old maps is undoubtedly difficult just because, on one hand, it assumes that there is an understanding of general cartography; on the other, a knowledge of the interpretative codes from the time period and the atmosphere of their production. The result made be a difficulty in their reading on the part of the general public both of the geometric content and the semantic content.
The fundamental idea is that of allowing anybody to extract information from the historic cartography, rendering more transparent the complex yet necessary operations of geo-referencing.
The preliminary remark is to recover the metrical content in historical maps (particularly perspective views of towns of XV-XVI century) using analyses which lead to a definition of a methodology for the quantitative analysis of historical cartography.
This implies to use procedures that treat of global and local transformations.
The plane transformations allow for the deformation of a map in a way which makes them assume the metric and geometric content of another reference map. This leads to the manipulation of the map being studied which consequently is subjected to warping, at times so great as to totally distort the original aspect. The price to pay for making a historic map metric according to modern parameters is that of losing some of the semantic content of the map itself. This situation is acceptable if it is then used for didactic and research purposes, but not if the map is being used by someone who wants to reads the map in its original form.
How can we join the desire to extract geometric information from a historical map while always maintaining the original aspect? The computer and the "*infographic*" come to help us: the solution is that of using software capable of putting in correspondence bi-univocal and visualising, interactively and in real time, a current numerical map of reference and a digital image of the historical map. The *2W* software presented in this paper responds to these characteristics.

For years, the historic cartography has been a subject of study by the historians and therefore, it has been considered as an archive document, a testimony of a certain period in the history of a territory, of a city. The study initiated and proposed in this paper faces, rather, the historic cartography according to an approach which is typical of the current cartography: extract territorial information which has been spatially referenced.
The historic cartography is surely a field in which the questions relating to the referencing assume great interest. It presents some common characteristics such as:

- a non definite reference system,
- an approximate projected system,
- an uncertain metric content,
- semantic content difficult to interpret.

Such characteristics in the maps and charts from varying eras are found in greater or lesser measures, and consequently, it is necessary to make specific considerations when faced with each and every individual map.
The fact remains that, in general, the assigning of a correct metric support is very important for the use in cartography, not only as a document for the archives, that is, of a qualitative nature, but a true cartography from which to extract quantitative information.
An idea that must guide and propel in this direction is that it is important to keep in mind that these charts have been created as charts, that is, with an operative and practical purpose, and that they were used as such. Perhaps the concept of metrics has changed, or more simply, the acceptable accuracy threshold has changed over the years.

A case study: Jacopo de' Barbari and the City of Venice in 1500

The study presented has concentrated primarily one the perspective views, which, if on the on hand, these have the advantage of being easily understandable in so far as the perspective is among the methods of representation which is most widespread, on the other hand, it is in fact, not measurable, if not by resorting to tricks which implicate a deep understanding of the descriptive geometry. The choice to use the perspective views of Venice by Jacopo de' Barbari was motivated not only by celebratory reasons (in the year 2000 it will be 500 years from the first year of the publication of the map), but especially for the geometric and cartographic characteristics of this map that represents the most exciting example of the new method of representation of the city based on perspectives. For the actual reference cartography for referencing, the photoplane of Venice was chosen.
The main problem was to understand whether the perspective construction of the work was quite rigorous, based on existing plans and charts, or whether it had been produced by a preliminary survey campaign, and in this case, which instruments and methods had been used.

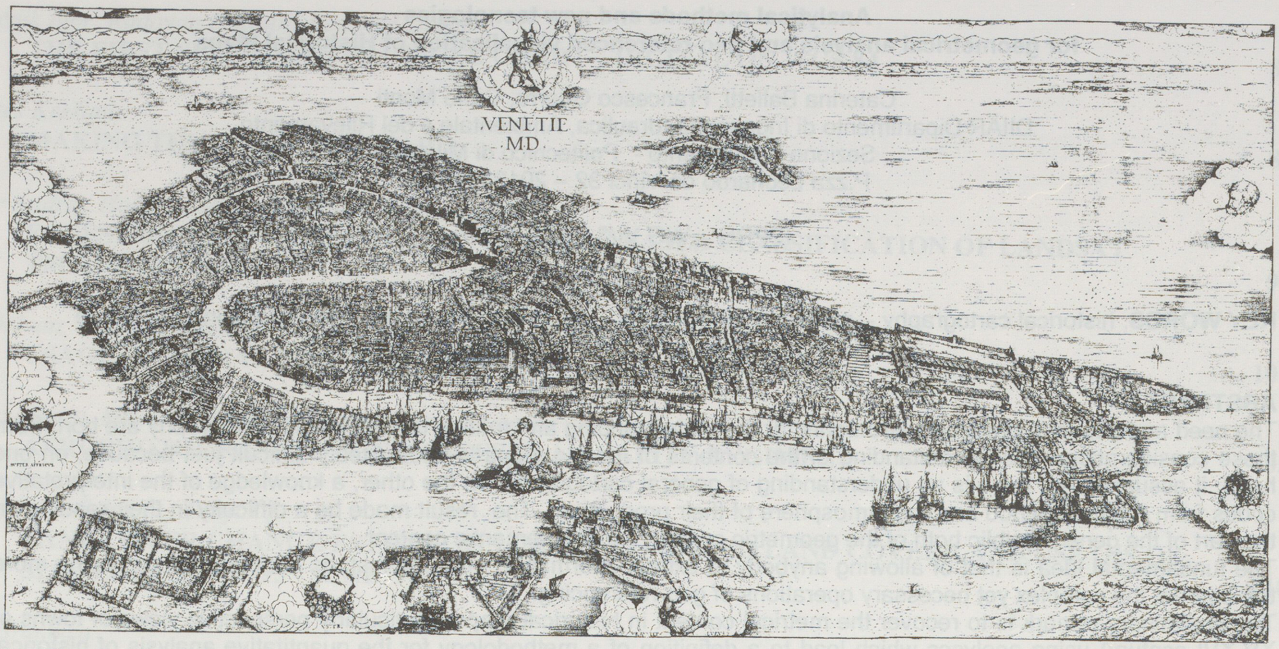

fig1 The perspective view of Venice of Jacopo de' Barbari

The idea that the perspective construction of the view might have been realised beginning with a plan and using elevations is fascinating for those involved in cartography because it presupposes the existence of a survey of the city or at least, given the particular character of the urban structure of Venice, of a series of reference points probably positioned in bell towers and surveyed using triangulation or a polar coordinates.
The studies have been addressed in part to evaluating the shifting of the view with respect to a "correct" geometry and on the other, to construct the instruments for understanding and fruition of the work for a general public which may not be specialised. The analysis and the spreading of the cartography, apparently quite far from each other, have an analytical and geometric apparatus in common: they are based on the same geometric and mathematical considerations and use the same instruments, the same calculation equipment, the same methods. These, although derived from the survey and modern analytical cartography disciplines, have assumed their own particular connotations and peculiarities, leading to a definition of a methodology for the quantitative analysis of the historic cartography.

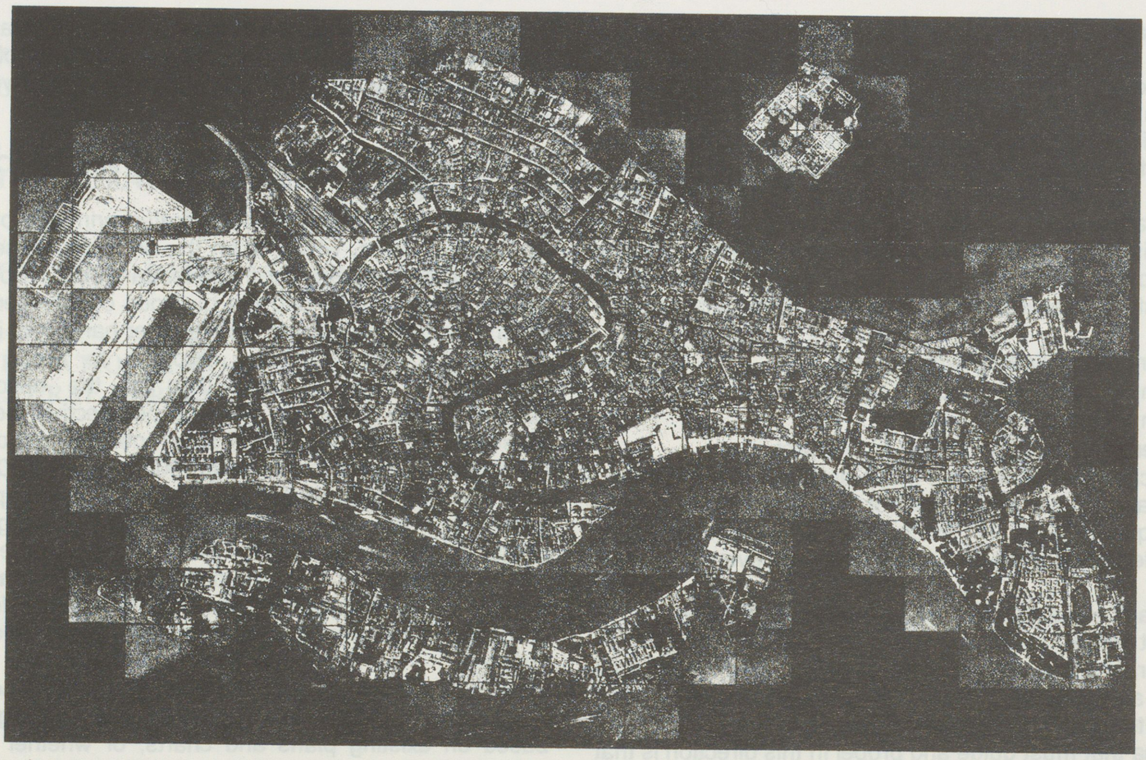

fig2 The photoplane of Venice utilized as the reference cartography

fig3 (upper) A perspective view of the actual plan of Venice obtained applying a projective transformation

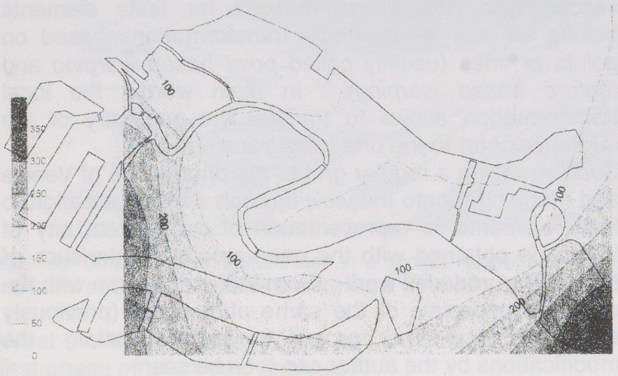

fig4 (left) Residual distribution of the projective transformation

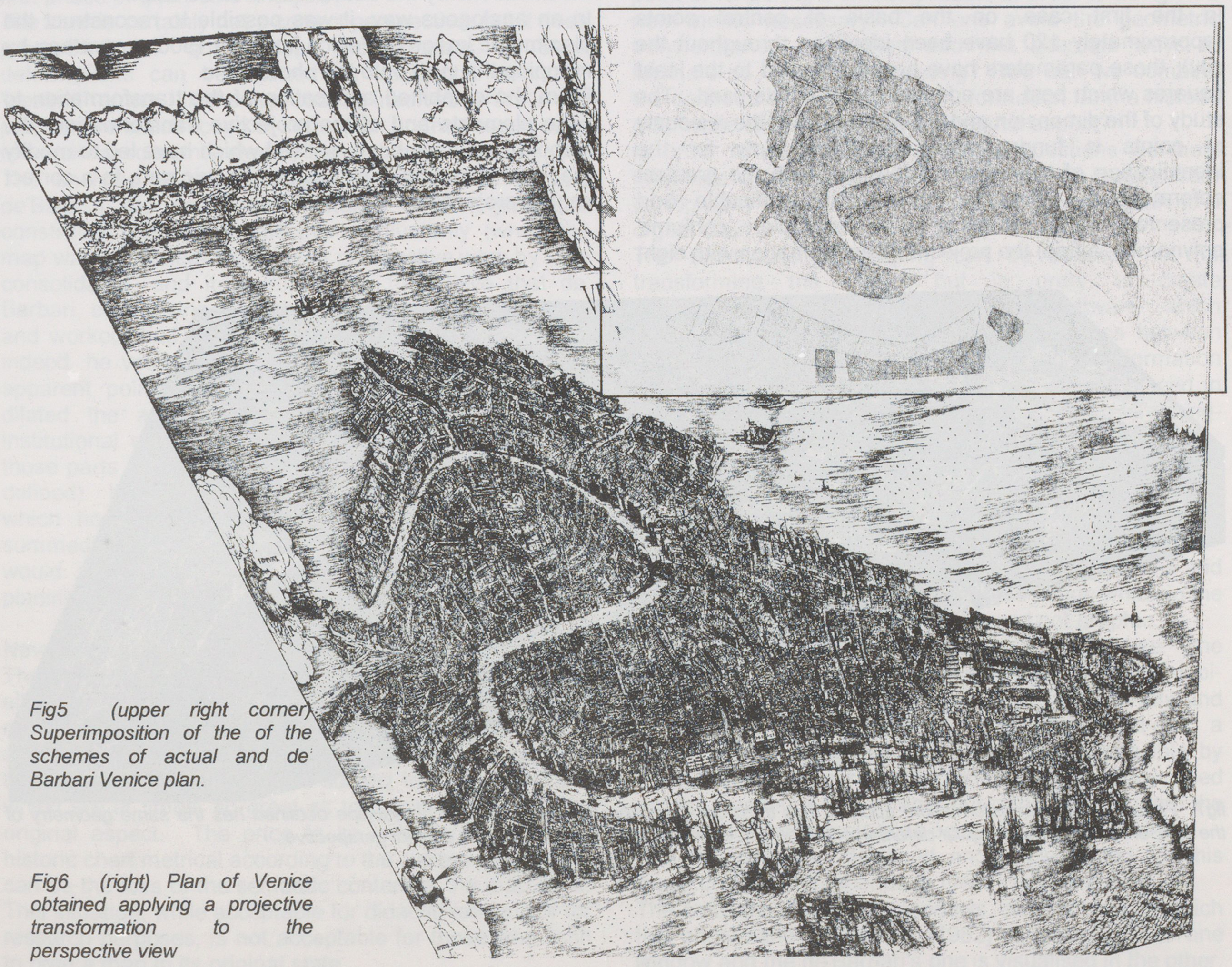

Fig5 (upper right corner) Superimposition of the of the schemes of actual and de Barbari Venice plan.

Fig6 (right) Plan of Venice obtained applying a projective transformation to the perspective view

The plane transformations for the study of the deformations

In the study of the view, the planimetric part was separated from the altimetric part, so that the information regarding the elevations were studied and evaluated separately. Even considering the view as a perspective construction based on geometric data surveyed directly or extracted from previous charts, the data on the elevations would result in not being easily worked with together with the planimetric data.
Considering, rather, that the attachment of the buildings to the ground, the canal side walkways and the canals themselves (places where the reference points have been positioned) lie practically on the same plane, the view of de' Barbari, relative to this plane, can be considered as the transformation of a planimetry of the city. Or rather, it is possible to obtain a view which corresponds geometrically to the city in the 1500's, taking an orthogonal projection of the city and modifying it according to a certain rule; that rule is a plane transformation.
The main problem was to understand what type of transformation it was better to use. The plane transformations can be divided into two large families: the global ones and the local ones. The first ones apply the same rule of modification to the entire chart, completing a transformation on the basis of different parameters. In other words, the first group of transformations corresponds to a rigid deformation while the second to an elastic deformation.
In the first case, on the basis of control points (approximately 120 have been identified throughout the city), those parameters have been estimated to the least squares which best are adapted to the points used. The study of the dimension and the distribution of the residuals of points is fundamental, as these allow for the identification of the zones of the map with the greatest deformations. Among the various applicable and presented transformations (for example, conform, polynomial, affine) the projective transformation with eight parameters has been chosen. This transformation is equal to the central projection of one plane on another, that is, in our case, to the placing in prospective of a planimetry. From this application, it was possible to evaluate the shifting of the view of Jacopo de' Barbari from a rigorous central projection.
Therefore, we proceeded with the inverse operation: applying a projective transformation to the prospective view in order to obtain the hypothetical plan of Venice in 1500. Even in this case, the result obtained emphasised the great differences between the historical chart and the current map.
In the case of the local transformations, rather, each point of the map is transformed according not to general fixed parameters, but to variable parameters which are calculated on the basis of nearby control points. To this second type, the transformations for finite elements belong as well as the local transformations based on points or lines (usually called *point based warping* and *feature based warping*). In plain words, the local transformation allows to transfer the geometry of the reference chart to the one to be transformed.
Superimposing a regular grid to the photoplane of Venice and mapping it onto the view through a transformation to finite elements, a representation of the current city of Venice is obtained with the geometric characteristics of the 1500's produced work. From the comparison with the correct prospective of the same photoplane (previously obtained from the projective transformation) the modifications by the author can then be seen.
In an analogous way, it was possible to reconstruct the planimetric image of Venice from the 1500's, or rather, by mapping the view onto the photoplane.
From the combined application of the transformation to finite elements and of the projective transformation, the elaborations have been realised which have led to modify the view, returning it, for the planimetric part, to a correct central projection.

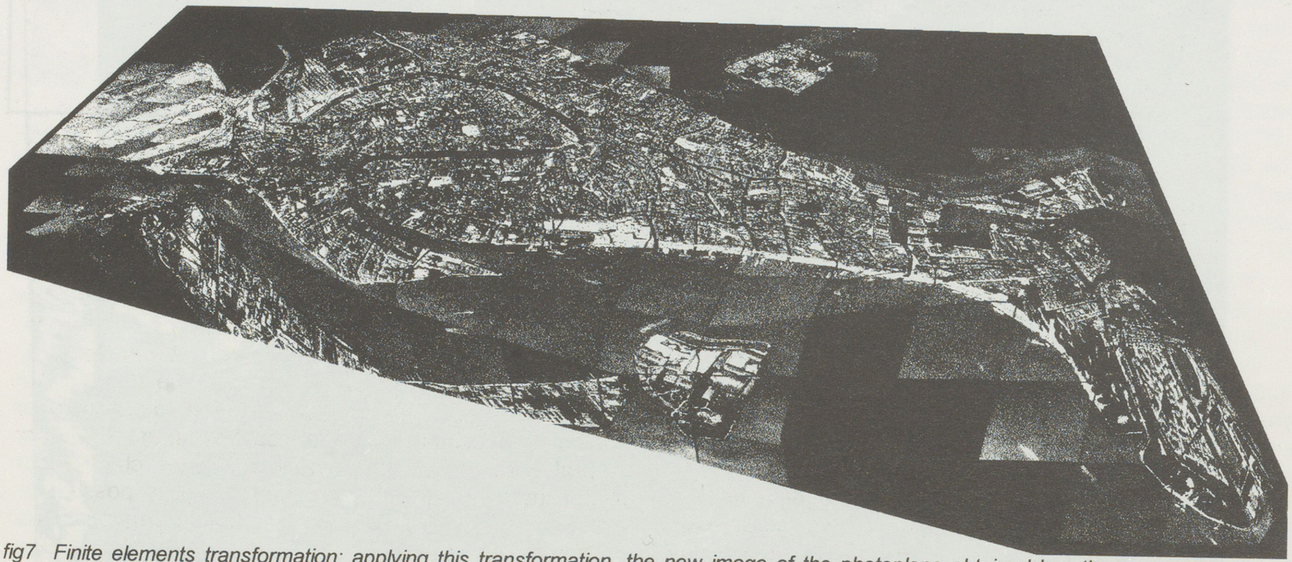

fig7 Finite elements transformation: applying this transformation, the new image of the photoplane obtained has the same geometry of the de' Barbari one. The irregular deformation of the grid underlines that the view is not a correct perspective.

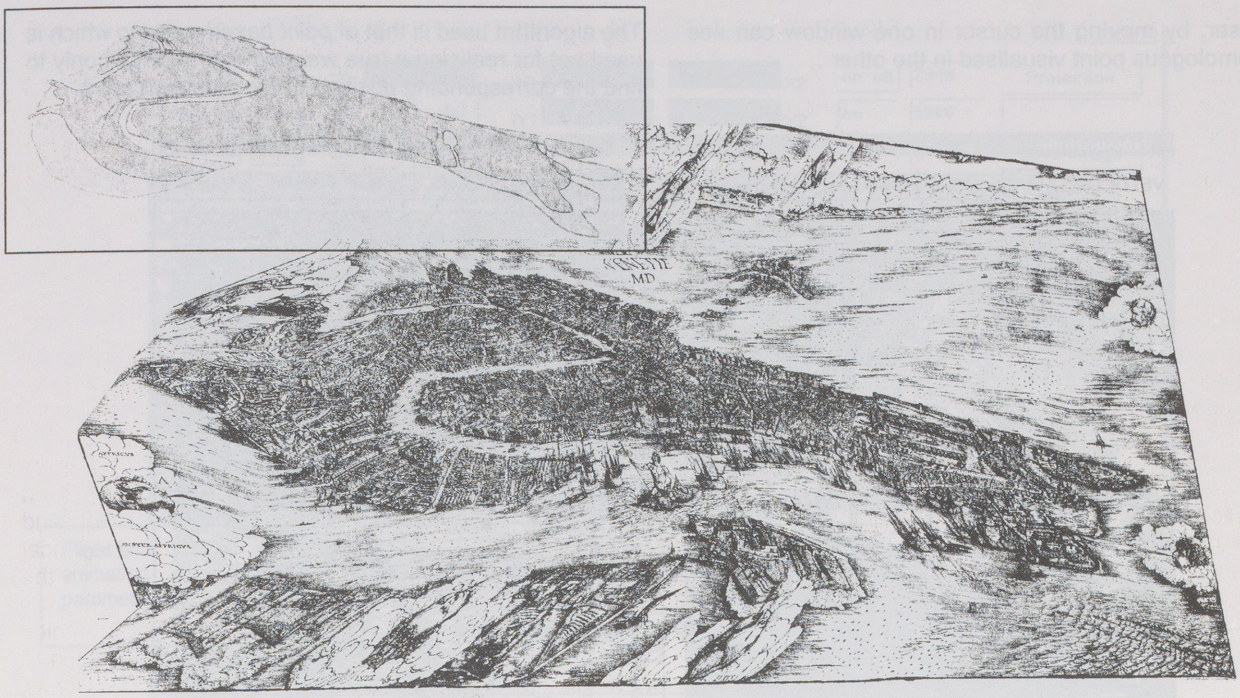

fig8 de' Barbari's view transformed in a correct central projection. In the upper corner the superimposition of the scheme of the original view and of the correct one to underline the deformations introduced by the author

What are the conclusions that can be obtained from this first phase of geometric analysis?
The view is certainly not a correct perspective, but it does present some quite clear deformations. Such deformations can be blamed on accidental errors or "desired" errors. In the first case, it involves errors in the perspective construction or in the plan, in the second case to a quite precise intention by the author.
The analysis done would lead to affirm that Jacopo de'Barbari did not make mistakes in the geometric construction of the perspective involuntarily (when the map was published, the rules of perspective were by then consolidated, and it is impossible to believe that de' Barbari, considering the cultural circles in which he lived and worked, had been incapable of applying them), but indeed, he voluntarily introduced these deformations for apparent political and symbolic reasons (in fact, he dilated the area of San Marco, the symbol of the institutional power of the city, while the map contracts those parts of the peripherical urban texture not yet well defined). It involves, therefore, some "political" errors to which however, the errors in the planimetry can be summed: from the geometric analysis of the planimetry, it would seem evident that he did not have a rigorous planimetry of the city available for use.

New technologies for historic cartography
The transformations dealt with in the first part of this text, allow for the deformation of a chart in such a way as to make them assume the metric and geometric contents of another reference chart. This leads to the manipulation of the chart in question, which is subject to the deformation which are at times, so great as to completely distort the original aspect. The price to be paid for rendering a historic chart metrical according to the current parameters can be the loss of the semantic content of the map itself. This situation, while acceptable for didactic reasons or for research purposes, is not acceptable for those who wish to read a map in its original state.
Is it therefore correct to distort the aspect of a map to the point of rendering it unrecognisable in order to assign it a new metric necessary? Can one avoid the geometric transformation of a chart and find alternate ways to facilitate its quantitative reading? How can we combine the desire to extract geometric information from a historic map while still maintaining the original aspect?
In order to positively answer these questions we must introduce a radical change in the way to benefit from cartography which must change from a paper chart to a digital chart.
The techniques of warping can be utilised, not for transforming the charts but in order to create correspondences, realising specific software which manage and visualise these correspondences between the charts. The procedure of referencing-transformation remains valid but is supported by and even replaced in some cases with the procedure of referencing-correspondence.
The analytic and algorithmic part of the two procedures is the same:

global transformations + local transformations (*warping*)

These change the ways to apply the transformations and change the support of the cartographic image which in the correspondence becomes numeric and not graphic.
Computer and "info-graphics" come to be of use: the solution is that of using software able to place in bi-univocal correspondence and visualise, interactively and in real time, a current numeric reference chart and a digital image of the historic chart. This is possible by using the analytic part of the plane transformations, used not for creating a new image, but rather, to calculate the positions of the homologous points on the two charts.
The *2W* software, designed and implemented for this research project, responds to these characteristics.
The software provides to windows, side by side, in which the photoplane of Venice (1982) is visualised in one window and the de'Barbari's one is visualised in the other.

The user, by moving the cursor in one window can see the homologous point visualised in the other .

The algorithm used is that of *point based warping* which is used not for realising a true *warping* operation but only to find the corresponding position of the identified point.

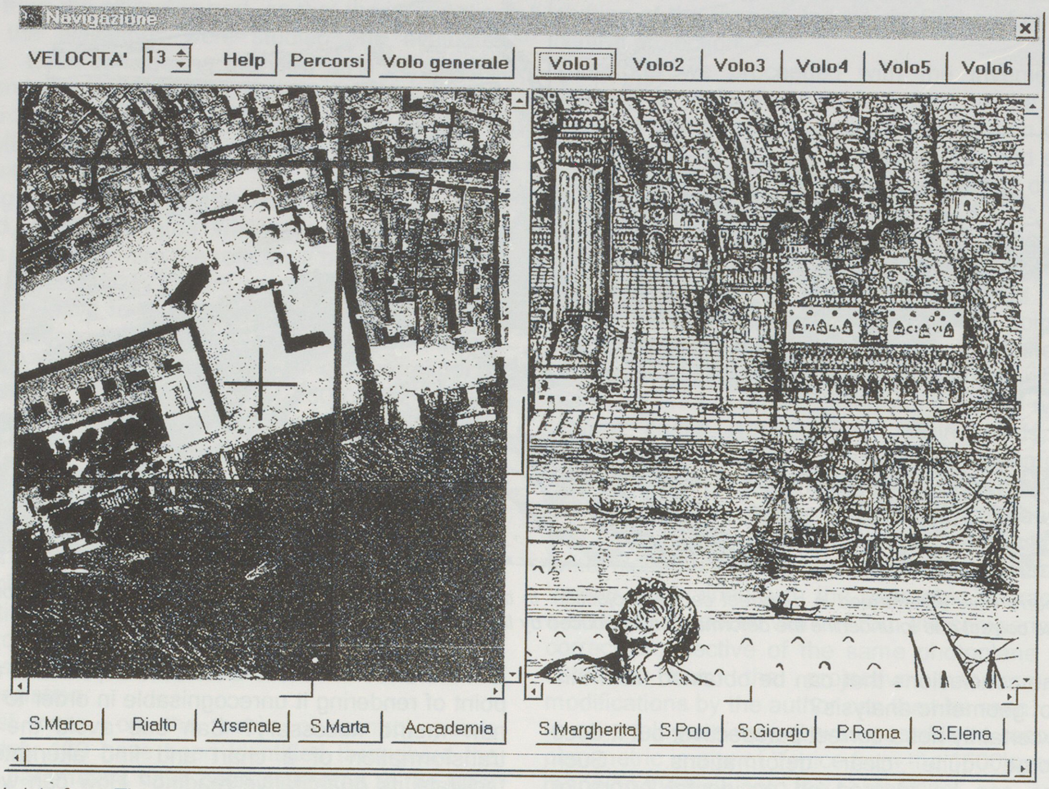

fig 9 2W user's interface. The crosses in the middle of the windows show the homologous points

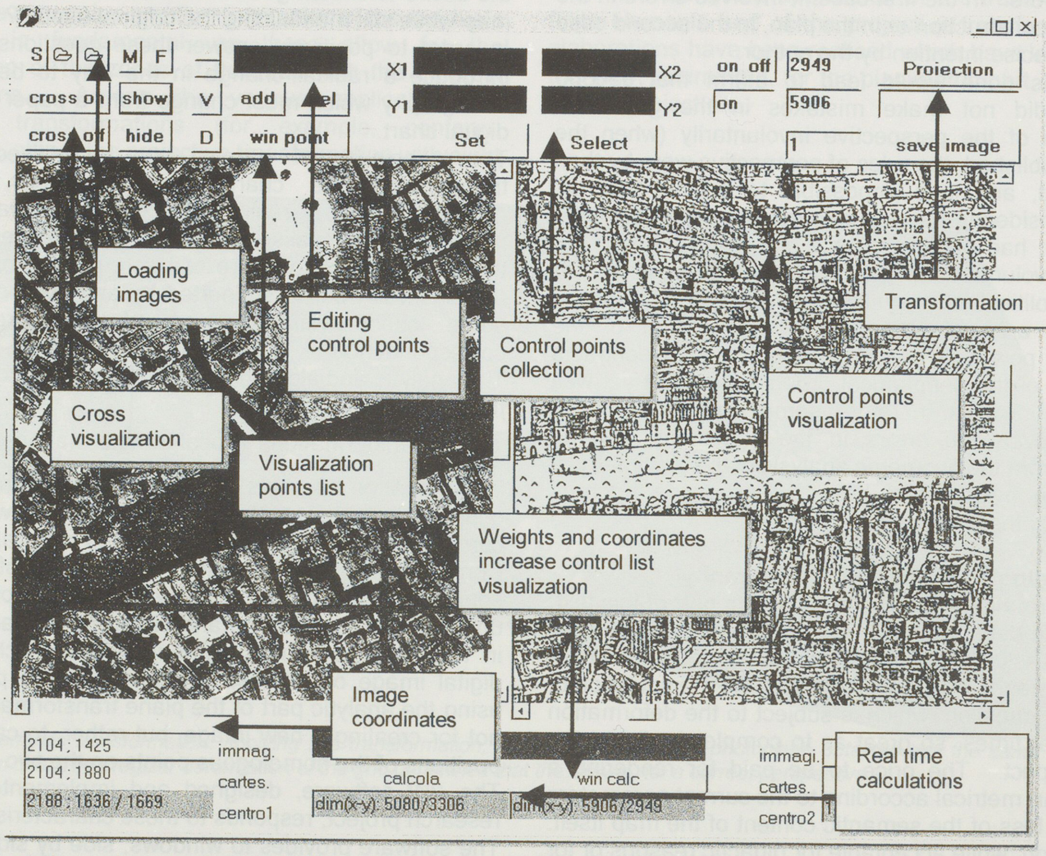

fig10 2W operator's interface: it allows to collect control points, to calculate coordinates in the new reference system and therefore to obtain the correspondence

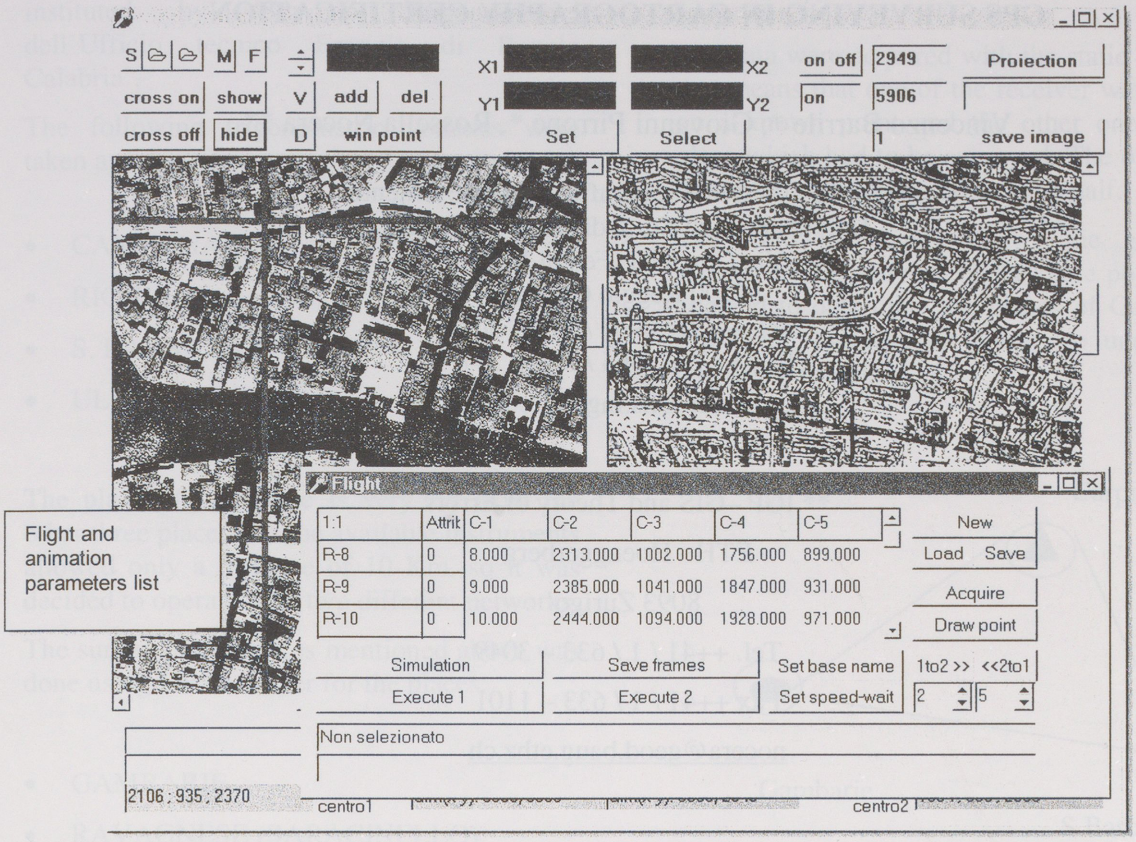

fig11 2W operator's interface (flight planning)

The set of reference points necessary for this algorithm to do calculations is the same one utilised in the part of the analysis of the transformations. This software allows therefore, for the user to know the actual position of each element designed by de'Barbari and to find on his view each place in the city as it is today. The limitations of the program are that of the algorithm: the correspondence is exact on the reference points while for all of the other points, it is obtained by interpolation.
In fact, the geo-referencing is complete.
The *2W* software allows the user to identify corresponding points and therefore to calculate the coordinates in the system of the reference chart.
These two actions:

- identify the points,
- know the coordinates of these points,

which are the fundamental operations which are done in cartography:

- localise,
- measure.

The software designed and implemented realises in a conclusive way the idea of the rigorous metric support return to historic cartography without however modifying the original aspect. This suggests therefore the need to reflect on the possibilities offered by the use of informational instruments in the field of cartography, and not only historic.

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